Joint Analysis of Seismic and Electromagnetic Data from the New Jersey Continental Margin: An Expansion

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LONG-TERM GOALS

- To improve our understanding of the relationships between sedimentary physical properties and geophysical parameters.

- To establish methodologies for the joint interpretation of independent geophysical data sets.

OBJECTIVES

Ambiguity in interpretation of geophysical data in terms of seafloor physical properties can be reduced if independent and complementary data sets are examined together. However, opportunities to carry out such analyses are rare. A cruise completed in 1998 featured coincident measurements of electrical resistivity and shear wave velocity across a series of buried paleo-channels on the New Jersey continental shelf. We propose to combine analyses of these two independent measures of seafloor structure to provide greater insight into the nature of the channels both in terms of the infilling material and the contrast in physical properties across the channel walls.

APPROACH

A cruise carried out in September 1998 had two main objectives focussed around areas where buried paleo-channels had been seen previously in high resolution seismic reflection profiles. These objectives were to measure the 2-D and 3-D shear-wave velocity structure of the uppermost 50m of sediments across the channels and also to measure the electrical resistivity structure of the channels.

It is well known that interpretations of a single physical parameter are subject to non-uniqueness. With resistivity for example, the conversion from resistivity to porosity requires assumptions to be made about the fluid distribution. The electrical resistivity of sediments is most commonly related to porosity by Archie's law. While we have seen reasonable agreement between porosity profiles

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inferred from resistivity and those measured in cores, combining measurements of two physical properties will greatly reduce the ambiguity by reducing the number of free parameters. This works as long as the two physical properties are sensitive to different aspects of the grain-fluid structure. While shear wave velocity also depends on sediment porosity, it also depends on the degree of coupling between the motion of the pore fluid and the sediment frame. This suggests that the measurements of electrical resistivity and seismic shear velocity that we plan to combine will be suitably independent.

Both 2-D and 3-D interface-wave tomography experiments were carried out at two locations where buried channels are known to exist in the uppermost 5-10 m of the seabed. The on-bottom source generates directly vertically-polarized shear waves. The receivers were autonomously recording seismographs with three-component seismometers that record ground motion with high fidelity in the band 5-50 Hz.

The EM experiment used the Canadian towed system used previously off northern California. We completed a total of 4 days of transmission including two regions of dense coverage in the same boxes where 3D seismic data from STRATAFORM were collected. The EM method used provides bulk porosity estimates to depths of around 20m below the seafloor and is thus able to place constraints on the nature of the channel infill and the contrast in physical properties across the channel boundaries. Our data show that a key condition for the channels to have an electrical signature is that they incise an underlying regional unconformity, **R**, thought to represent a subaerially eroded surface, exposed during the late Wisconsinan glaciation. Channels that cut **R** are seen through increases in apparent porosity. Another seismically imaged channel sequence, which lies within the outer-shelf sediment wedge sequence above **R**, does not have an electrical signature, indicating that the sediments above and below the channel boundaries have similar physical properties.

An example of how resistivity and seismic data can be combined to predict fluid distributions is given in Evans (1994). In this case, examining the relationship between resistivity and compressional wave velocity and comparing this relationship against combinations of empirical relationships allowed inference of the permeability structure of the oceanic crust. Our approach will be to similarly combine the distributions of electrical and shear wave velocities across the channels. Key properties we hope to resolve are the nature of the material infilling the channels and the contrast in physical properties across the channel walls.

WORK COMPLETED

The large amount of seismic data has been reduced and shear wave arrival times picked for all experiments. Data analysis is underway and final analysis and interpretation should be completed shortly. The electrical resistivity data have been further analysed, resulting in a publication describing the channel structures from an electrical viewpoint.

Resistivity depth profiles obtained from EM surveying of continental shelf sediments provide an alternative and reliable means of mapping sediment properties. While the technique is not able to delineate thin layers of variable porosity, the system is able to identify high porosity deposits extending a few tens of centimeters into the seafloor and provides a low-pass filtered version of the

shallow porosity structure. Given that the EM system has reasonable resolution near the seafloor, and that the shallowmost apparent porosity is biased by the shallowmost structure, we have investigated links between these apparent porosities and acoustic backscatter data from New Jersey and also in the Californian STRATAFORM area.

RESULTS

For both the Eel River and New Jersey regions, we have extracted sidescan backscatter amplitudes from existing data sets at points co-incident with our EM data. We have examined links between the two data types and find reasonable correlations between the shallow porosity and backscatter in primarily sandy regions. However, the inclusion of mud into the surficial sediment removes this correlation, suggesting, as have others, that sands and muds have inherently different scattering mechanisms that result in two different relationships between porosity and acoustic backscatter. A further complication is seen across sand-ridges off New Jersey, where the presence of shell hash in the near surface at the crests of these ridges results in a change in grain sphericity and hence changes in the Archie's law parameterisation used to infer porosity from resistivity.

IMPACT/APPLCATIONS

The establishing of methodologies for the joint interpretation of seismic and electrical properties will have ramifications for a wide variety of geophysical investigations. The importance of carrying out joint surveys has been noted in many situations and is not confined to those measuring sedimentary properties, but includes programs such as the MELT experiment, the largest seafloor geophysical survey undertaken measuring the properties of the mantle beneath a fast spreading midocean ridge.

Others have suggested the difficulty of using acoustic backscatter as a sole determinant of sediment type: we suggest that porosity estimates from EM surveys might provide a useful additional constraint allowing more accurate sediment classification
over large areas.

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PUBLICATIONS

Evans, R.L., L.K. Law, B. St. Louis, S. Cheesman, Buried paleo-channels on the New Jersey continental margin: channel porosity structures from electromagnetic surveying, Marine Geology, in press.

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